Design Development of the General Aviation Enhanced Head-Up Display

For the
Quarterly Review of the NASA/FAA Joint University Program for Air Transportation Research
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Project Sponsor: Joint University Program

Introduction

- General Aviation Instrumentation has undergone little change in the past 50 years.
- In 1999, 73% of the fatal accidents occurred in night Instrument Meteorological Conditions (IMC).
- IFR traffic is expected to increase by 2.5 percent per year over the next decade.
- Increase in IFR traffic might lead to a possible increase in GA accidents.

Overview

- Motivation Behind Enhanced Head-Up Display
- Pseudo-Attitude Determination
- Flight Test and Data Analysis
- Enhanced Head-Up Display System Overview
- Flight Display Software
- Enhanced Head-Up Display Implementation
- Enhanced Head-Up Display Features

Overview Continued

- Situational Awareness Prompts and Symbols
- Concerns and Problems with the eHUD
- Future Work

Motivation Behind eHUD

- Provide Visual Cues in IMC
- Increase Situational Awareness in IMC
- Reduce Pilot Training and Recurrency Requirements for Flight in IMC
- Keep the Pilot Looking out the Window at the Same Time they are Flying the Instrument Approach
- Cost Effective Head-Up Display

Attitude

The Merriam-Webster Dictionary defines *attitude* as the position of an aircraft or spacecraft determined by the relationship between its axes and a reference datum.

Traditional Attitude:

- Three GPS Receivers, three Antennas.
- Expensive and Computationally Intensive.

Pseudo-Attitude (*Velocity Vector Based Attitude*):

- Observable from a single GPS antenna.
- Cost effective to purchase and install.

Pseudo-Attitude Determination

(*Velocity Vector Based Attitude Determination*)

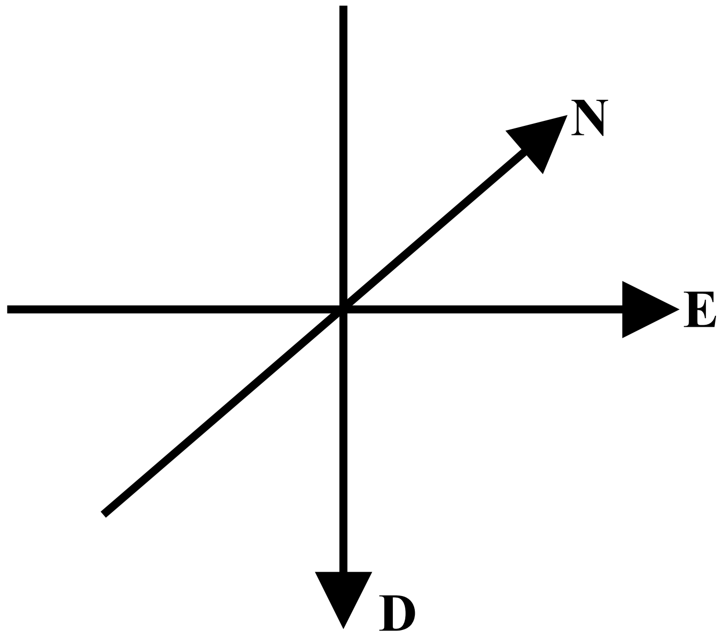
Developed at the Massachusetts Institute of Technology by:

- Dr. Richard P. Kornfeld
- Dr. R. John Hansman
- Dr. John J. Deyst

The information on the following slides, regarding Velocity Based Attitude, was taken from "***The Impact of GPS Velocity Based Flight Control on Flight Instrumentation Architecture***" Report No. ICAT-99-5, June 1999.

Reference Frame

(*North, East and the Local Vertical Down.*)



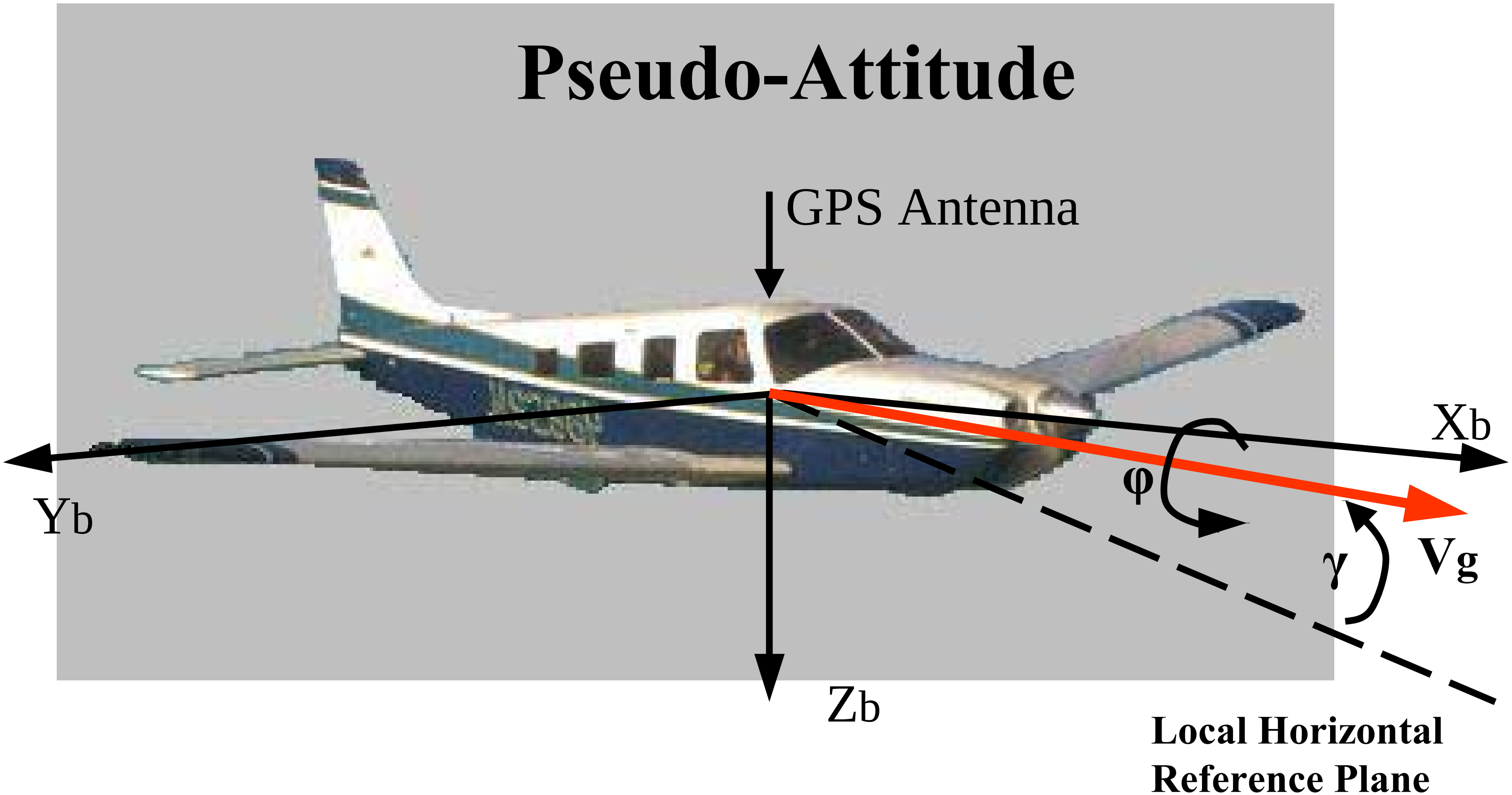
$$\mathbf{N} \times \mathbf{E} = \mathbf{D}$$

Velocity Vector

$$V_g = (V_{gN}, V_{gE}, V_{gD})$$

FNED: Earth-Fixed locally level coordinate system.

Pseudo-Attitude



Flight Path Angle : **γ**

Pseudo-Roll Angle : **φ**

***F*_B:_** Body-fixed orthogonal axes set which has its origin at the aircraft center of gravity.

Data Collection Flight Test

- Flight Test Conducted 18 November, 2001
- Consisted of Four Touch-and-Go Landings on UNI Runway 25, Followed by Banking Maneuvers
- GPS Antenna Mounted Approximately Above Aircraft Center of Gravity
- BESTPOSA GPS String Collected at 20 Hz
- BESTVELA GPS String Collected at 20 Hz

Position and Velocity Strings

Position (BESTPOSA)

- GPS Sec into the Week
- Latitude
- Longitude
- Height

Velocity (BESTVELA)

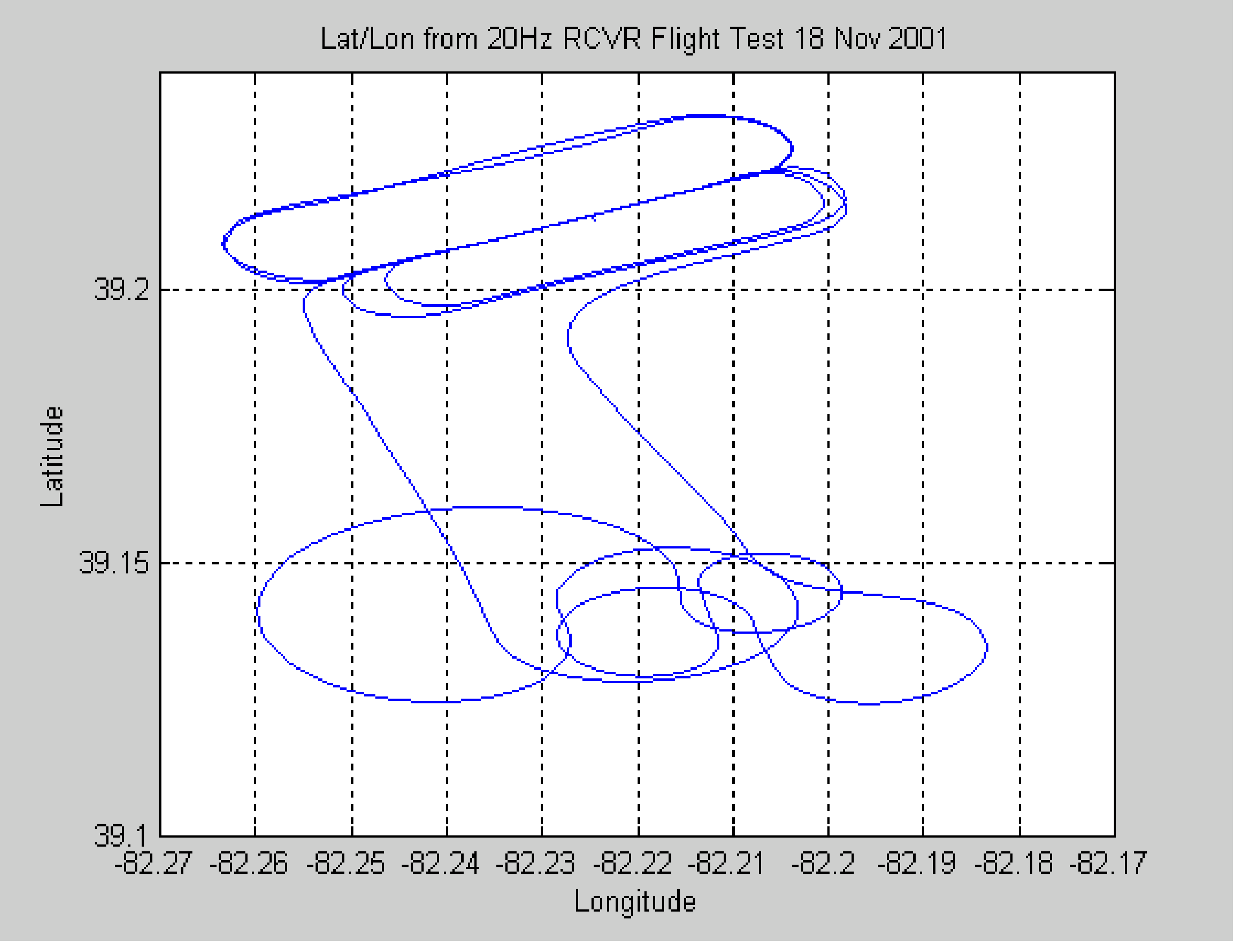
- GPS Sec into the Week
- Horizontal Speed (m/s)
- Ground Track (degrees)
- Vertical Speed (m/s)

Latitude, Longitude, and Height (LLH) Converted to East, North, and Up (ENU) for use in Flight Data Parameter Set.

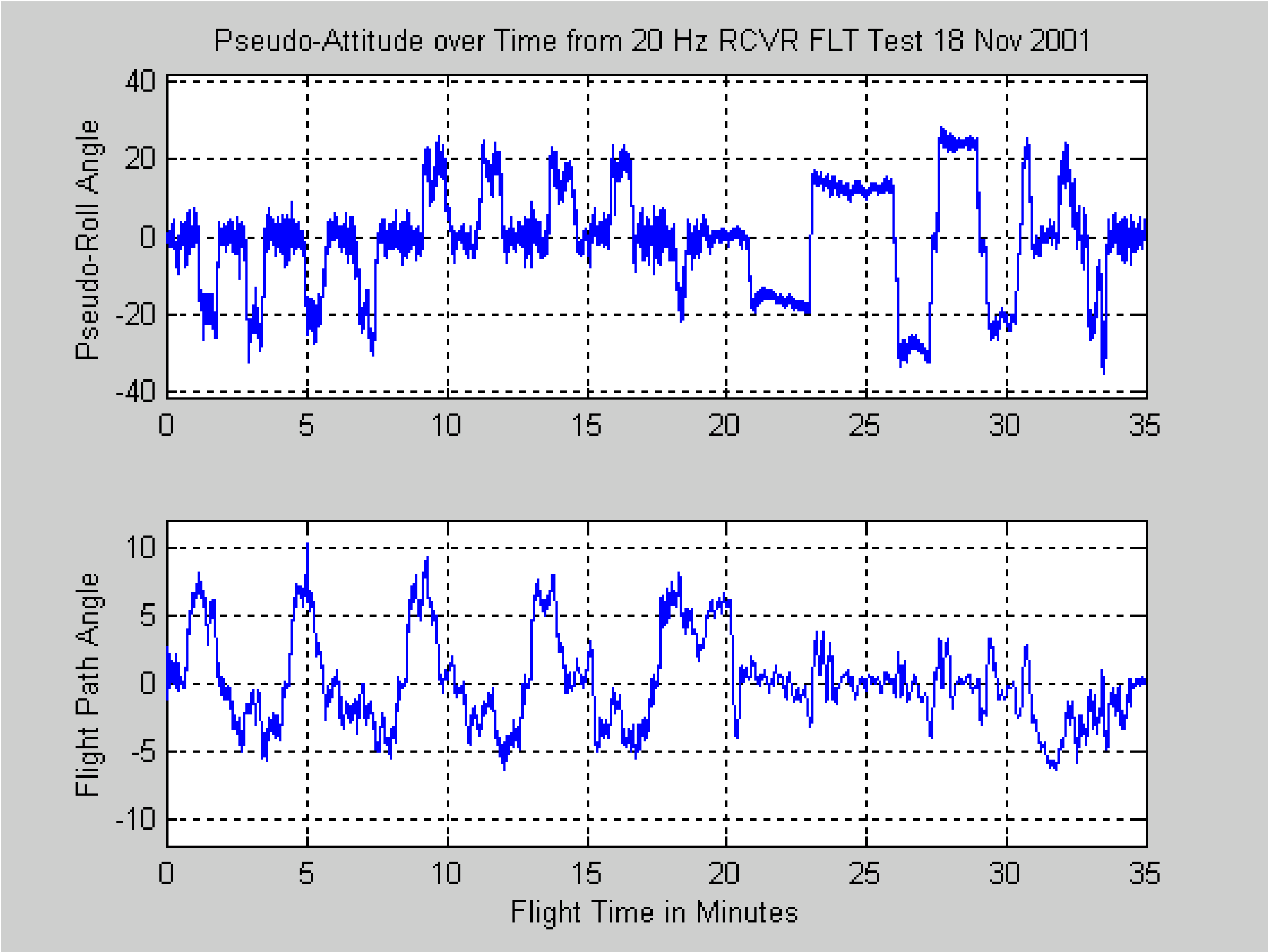
Flight Data Parameters

1. Time-stamp (GPS Seconds into the Week)
2. Local East (meters)
3. Local North (meters)
4. Height (meters)
5. Ground Speed (m/s)
6. Ground Track (degrees)
7. Flight Path Angle (degrees)
8. Pseudo-Roll (degrees)

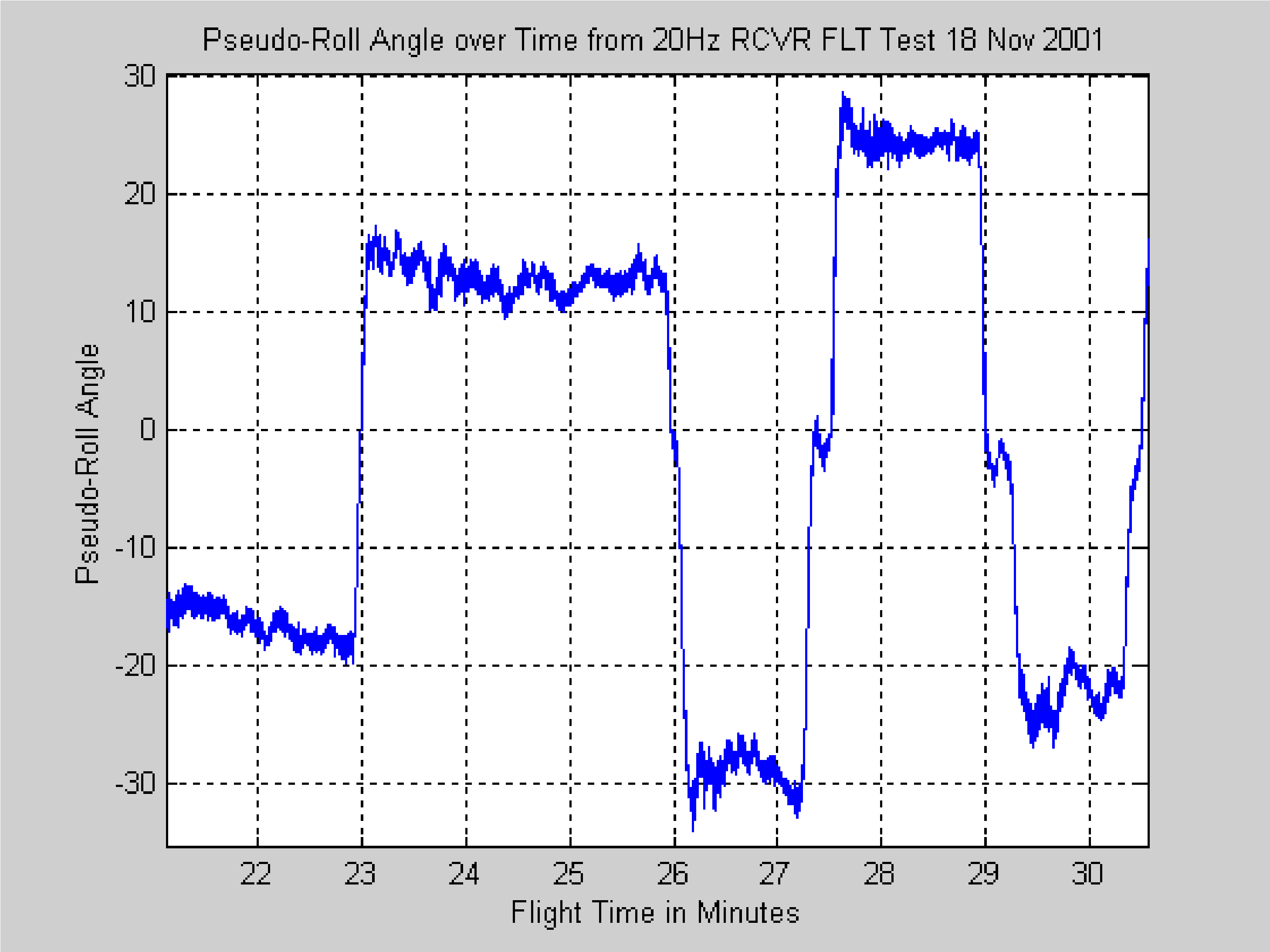
Data Collection Flight Path



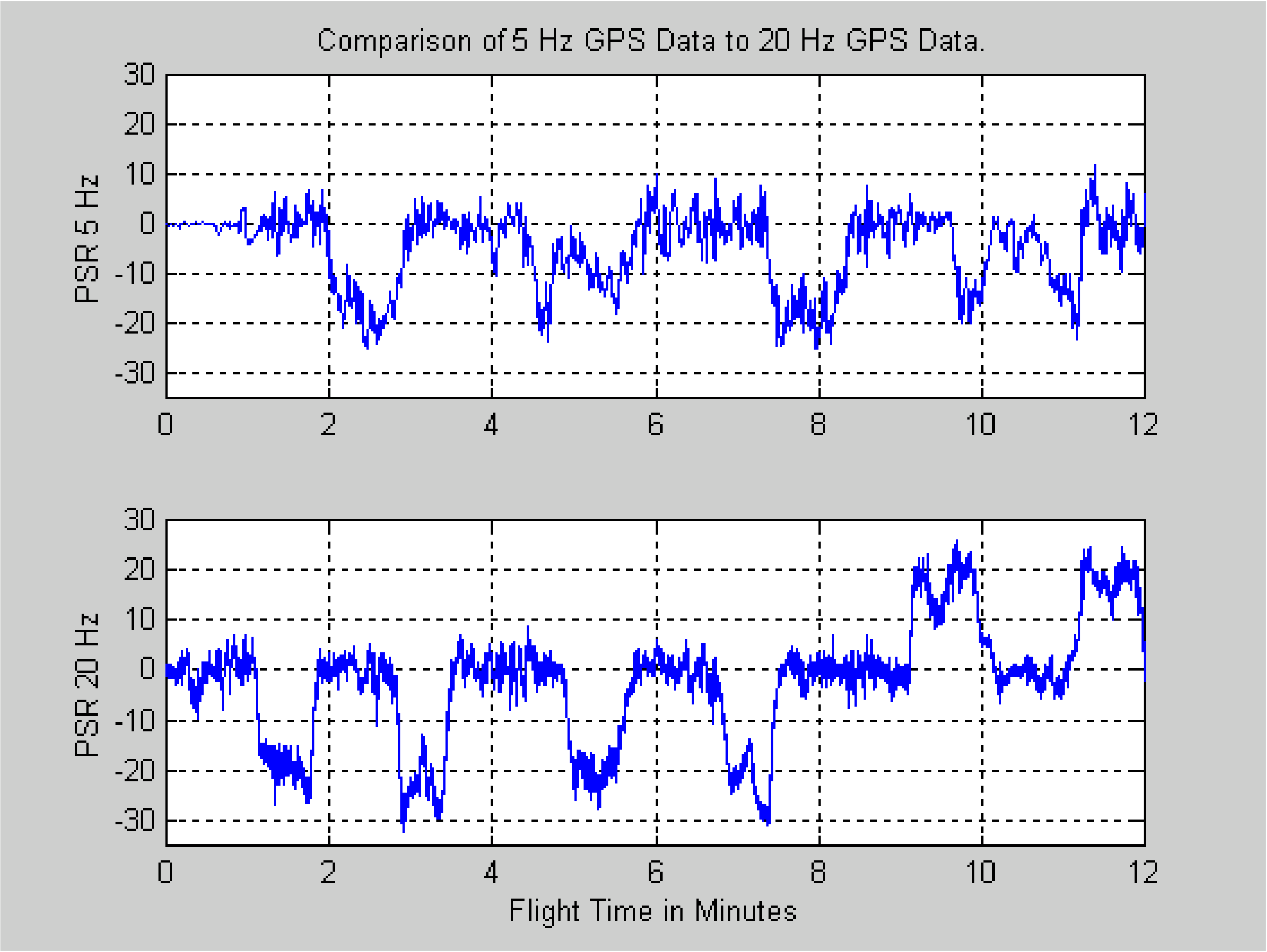
Pseudo-Attitude



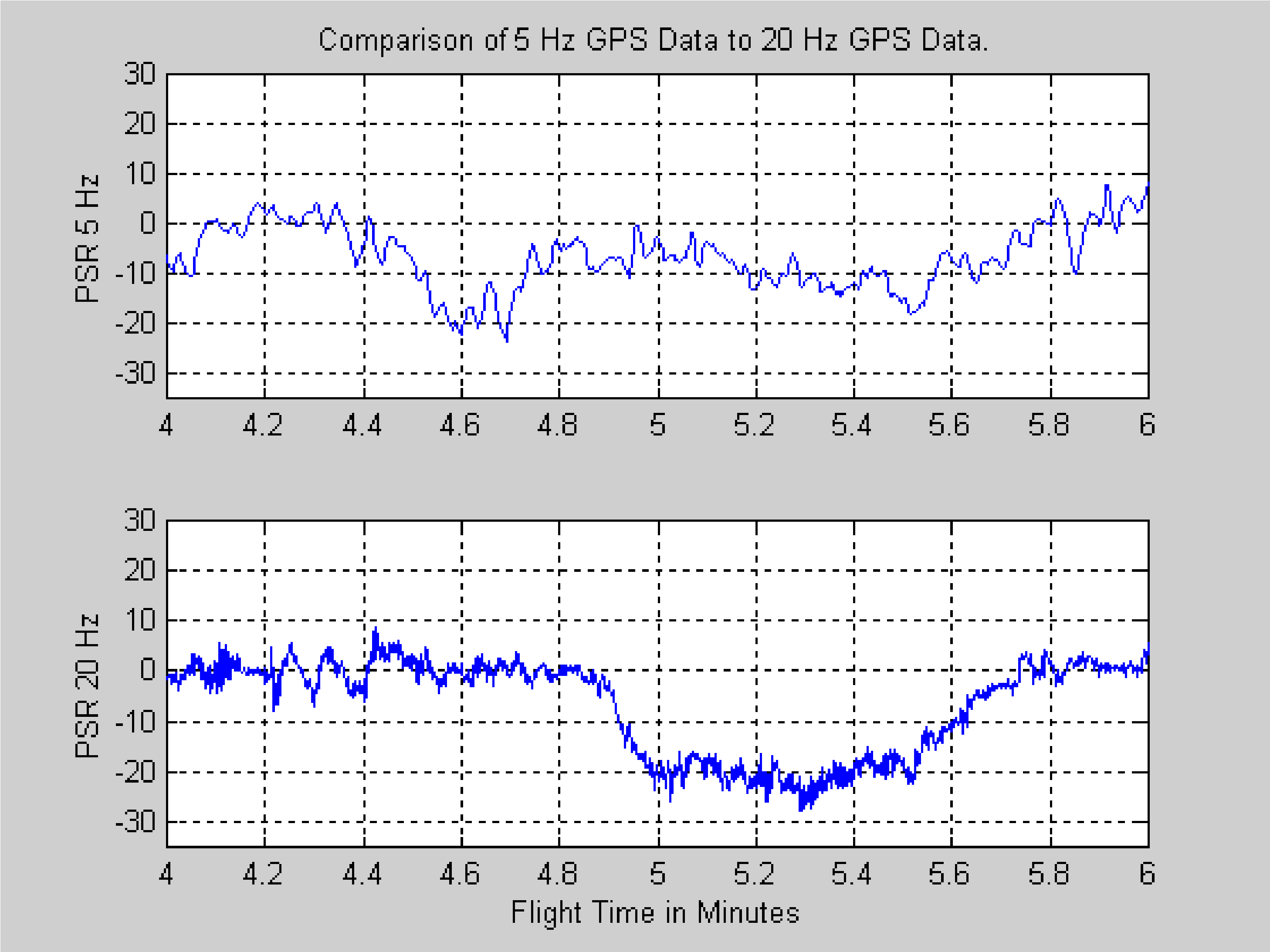
Closer Look at the Pseudo-Roll



Pseudo-Roll Comparison



Resolution Comparison

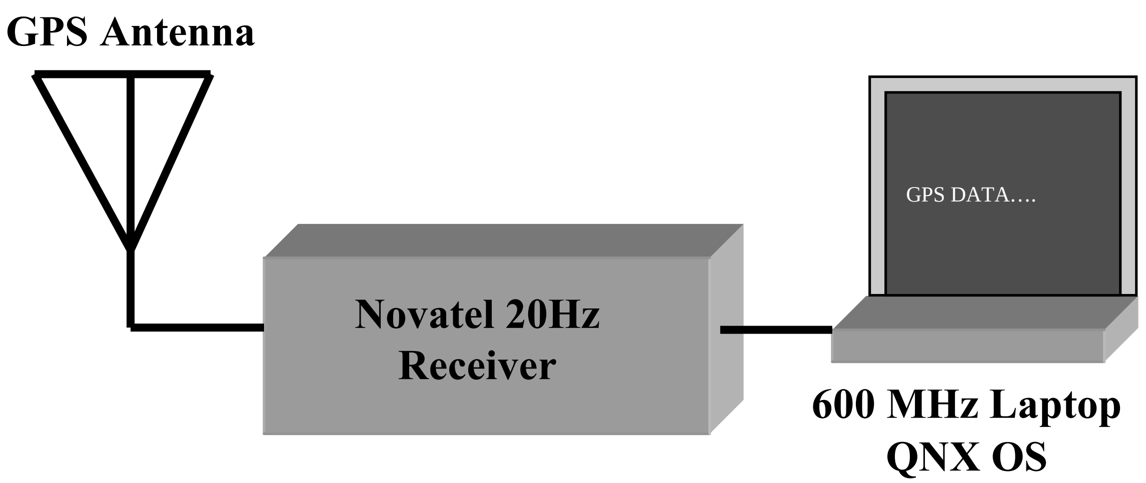


Real-Time Flight Test

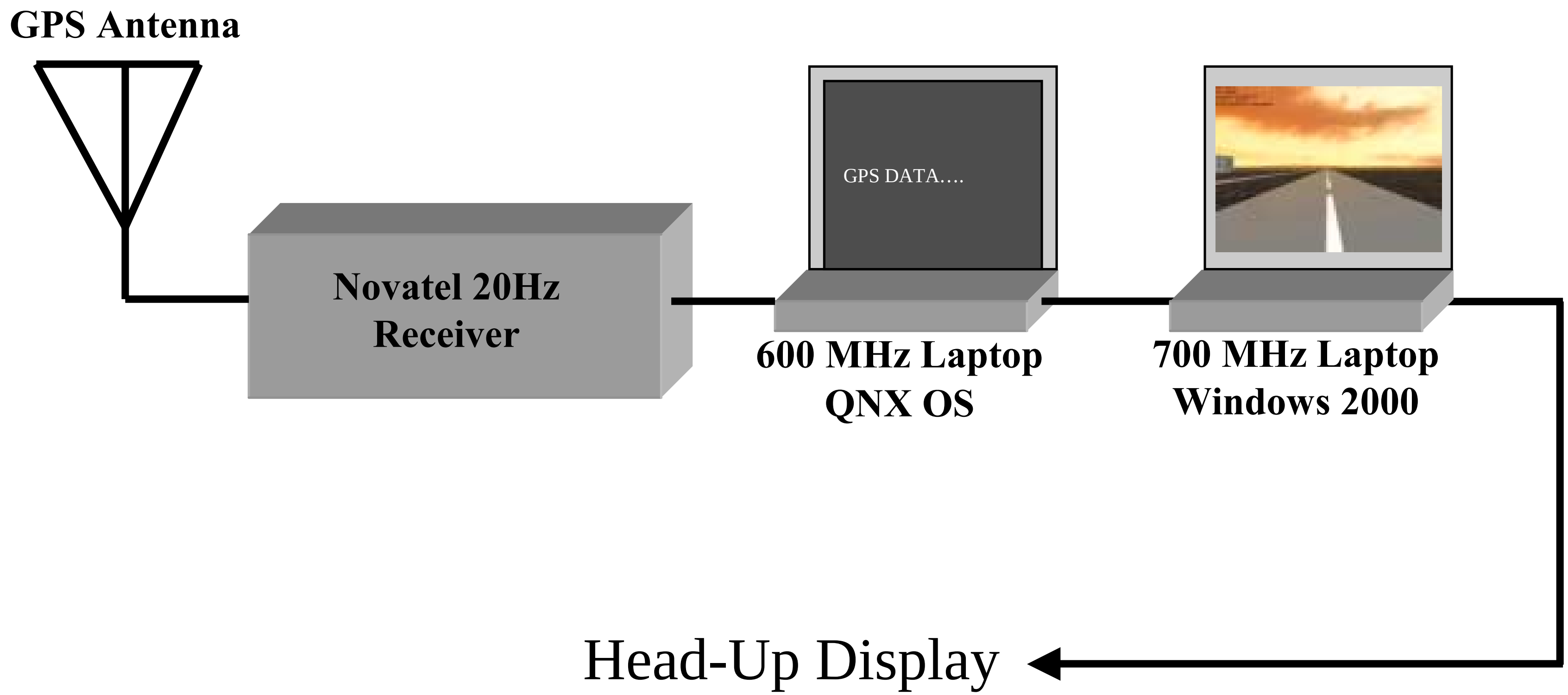
- Conducted on 2 January, 2002
- OEM-4 GPS Receiver Connected to 600 MHz Laptop
- Pseudo-Roll Angle and Flight Path Angle Were Calculated at 20 Hz
- The GPS Time, Pseudo-Roll Angle, and Flight Path Angle Were Displayed as Text at 5 Hz

Results: Velocity Vector was Processed Real-Time with Accurate Results.

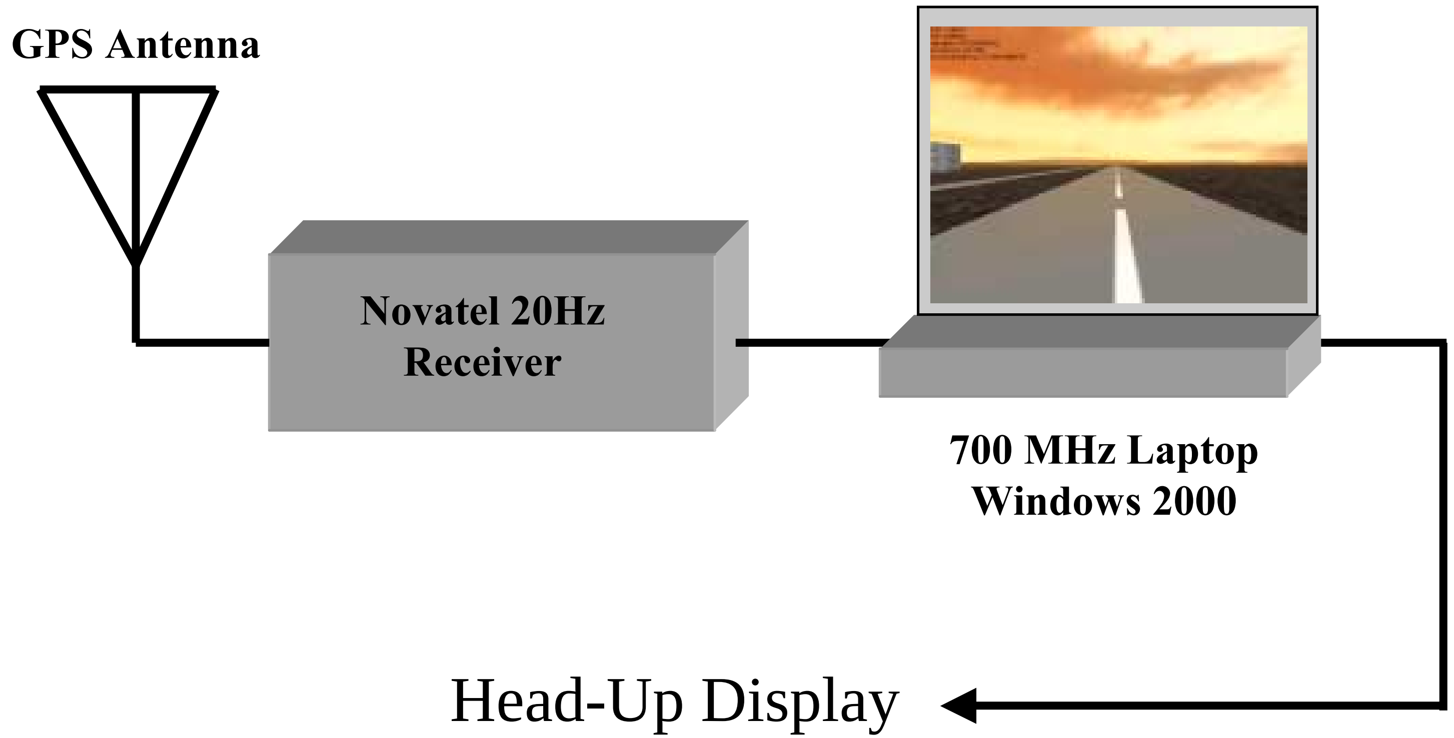
Flight Test Configuration



Previous eHUD Configuration



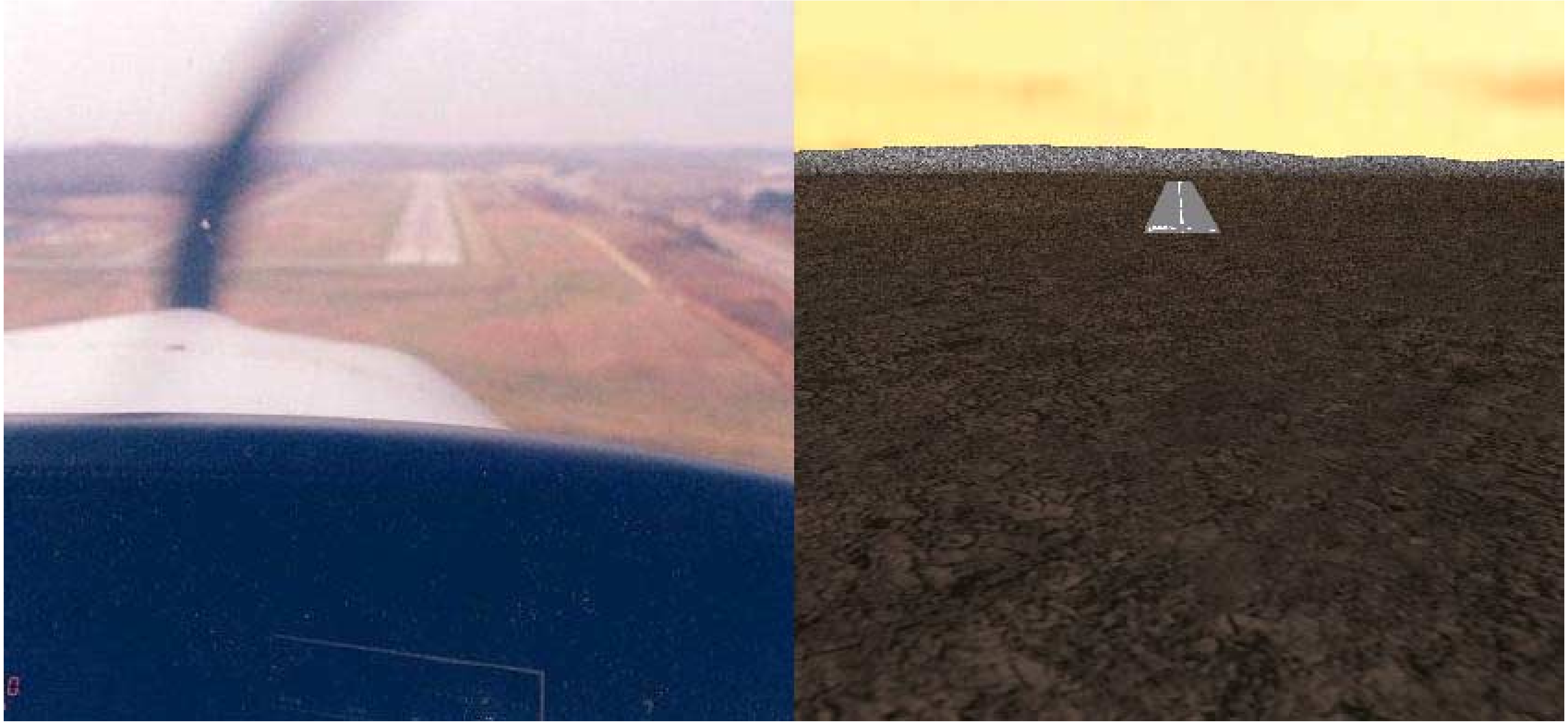
Current eHUD Configuration



Data Processor and Display Processor

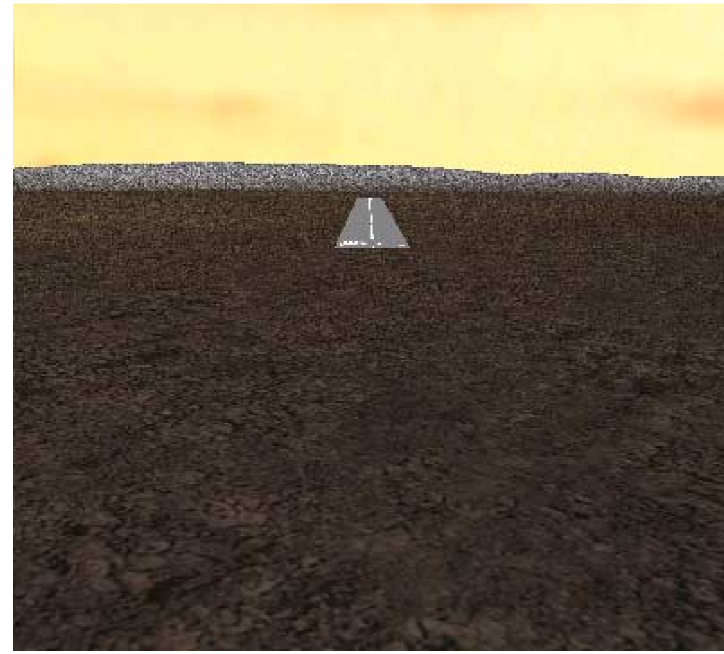
- 700 MHz Laptop Running Windows 2000
- Attitude Determination Algorithm Performed in C++ DLL
- Display Written in Visual Basic
- Graphics Produced Using Revolution 3D Graphics Engine
- Three-Dimensional Representation of the Outside World

Synthetic Vision Comparison

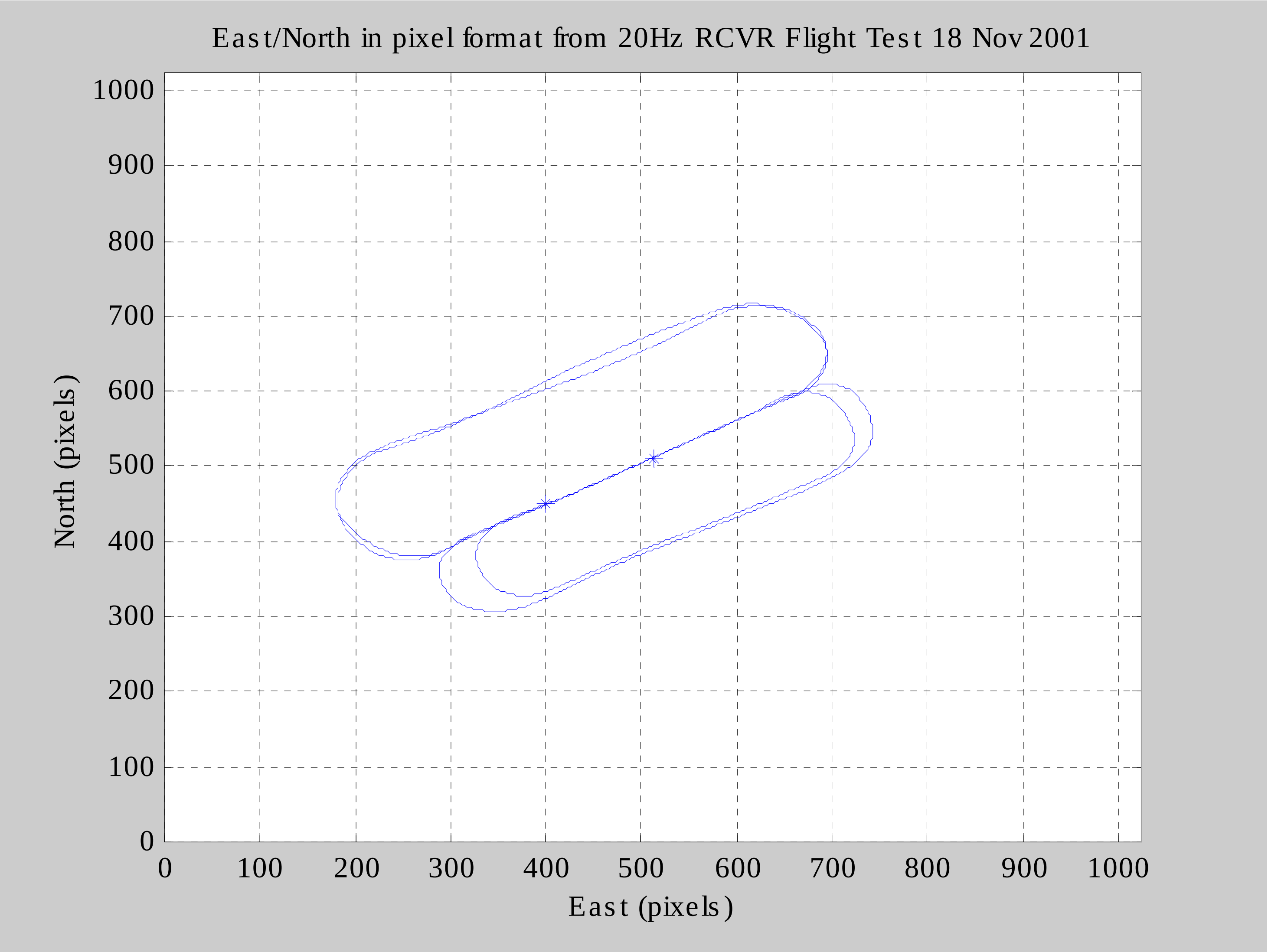


The above images represent two different flights to UNI runway 25. They are provided as a rough comparison between an actual approach and the synthetic vision display.

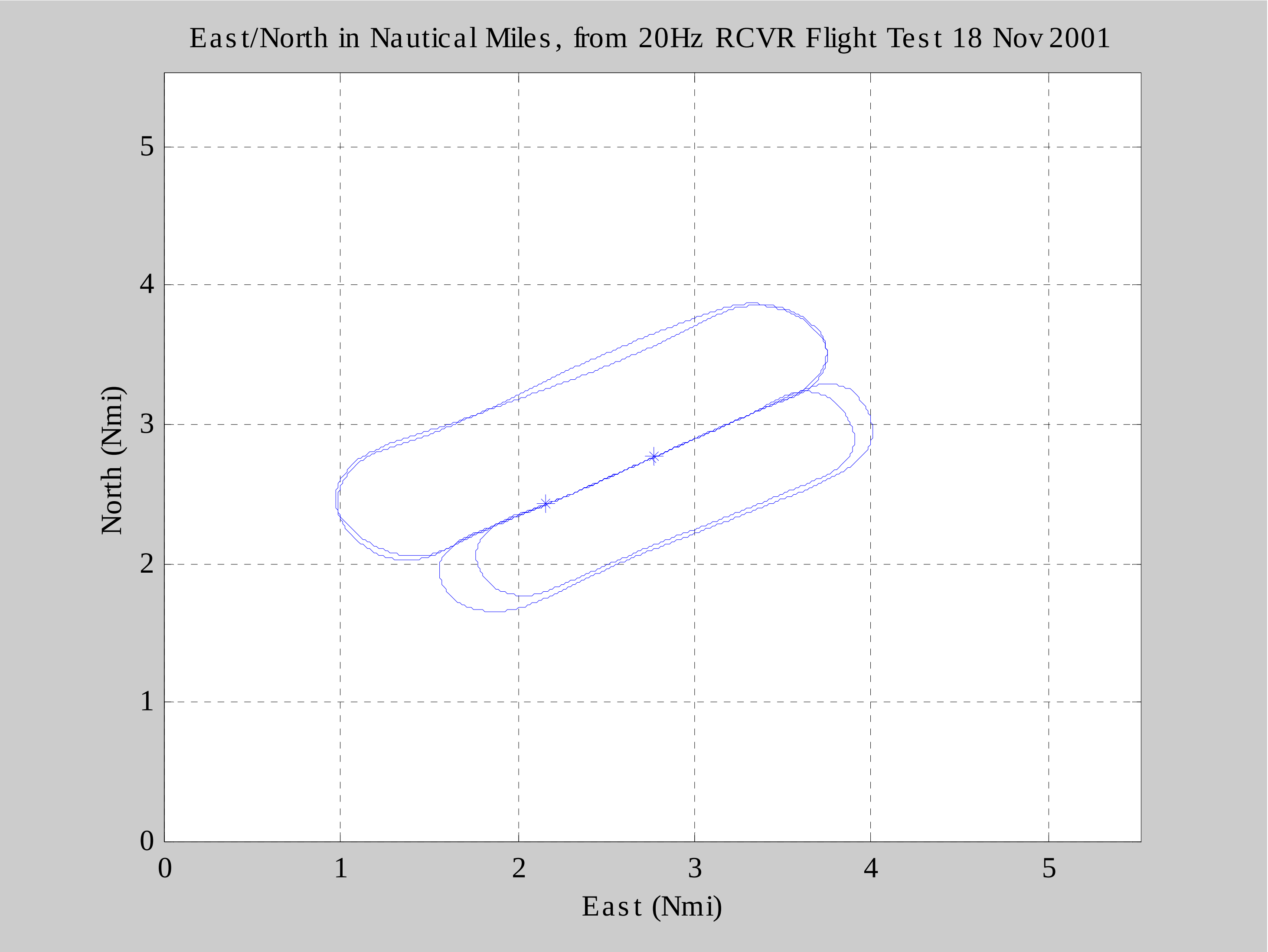
Image Layers



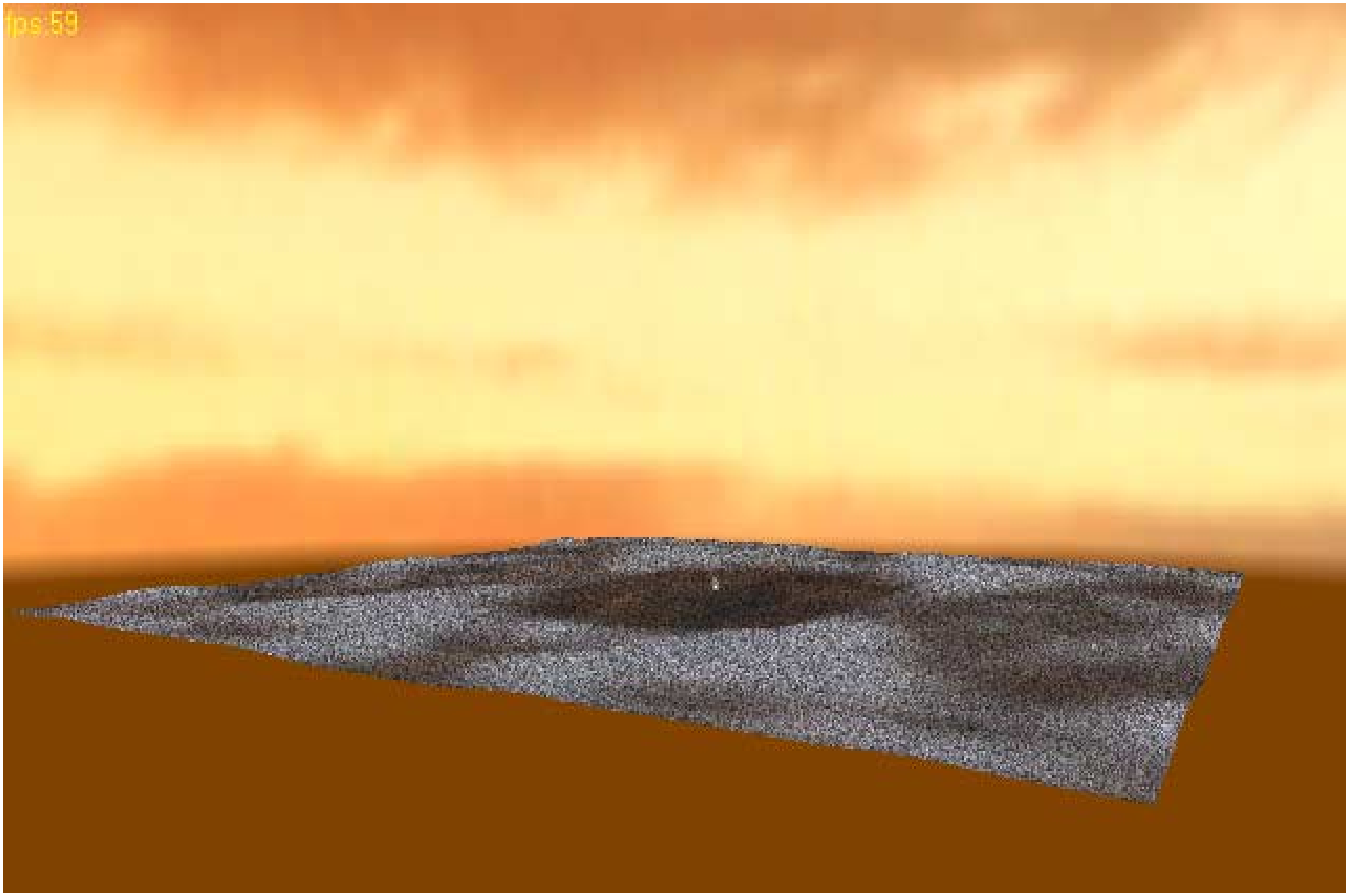
Terrain Boundary



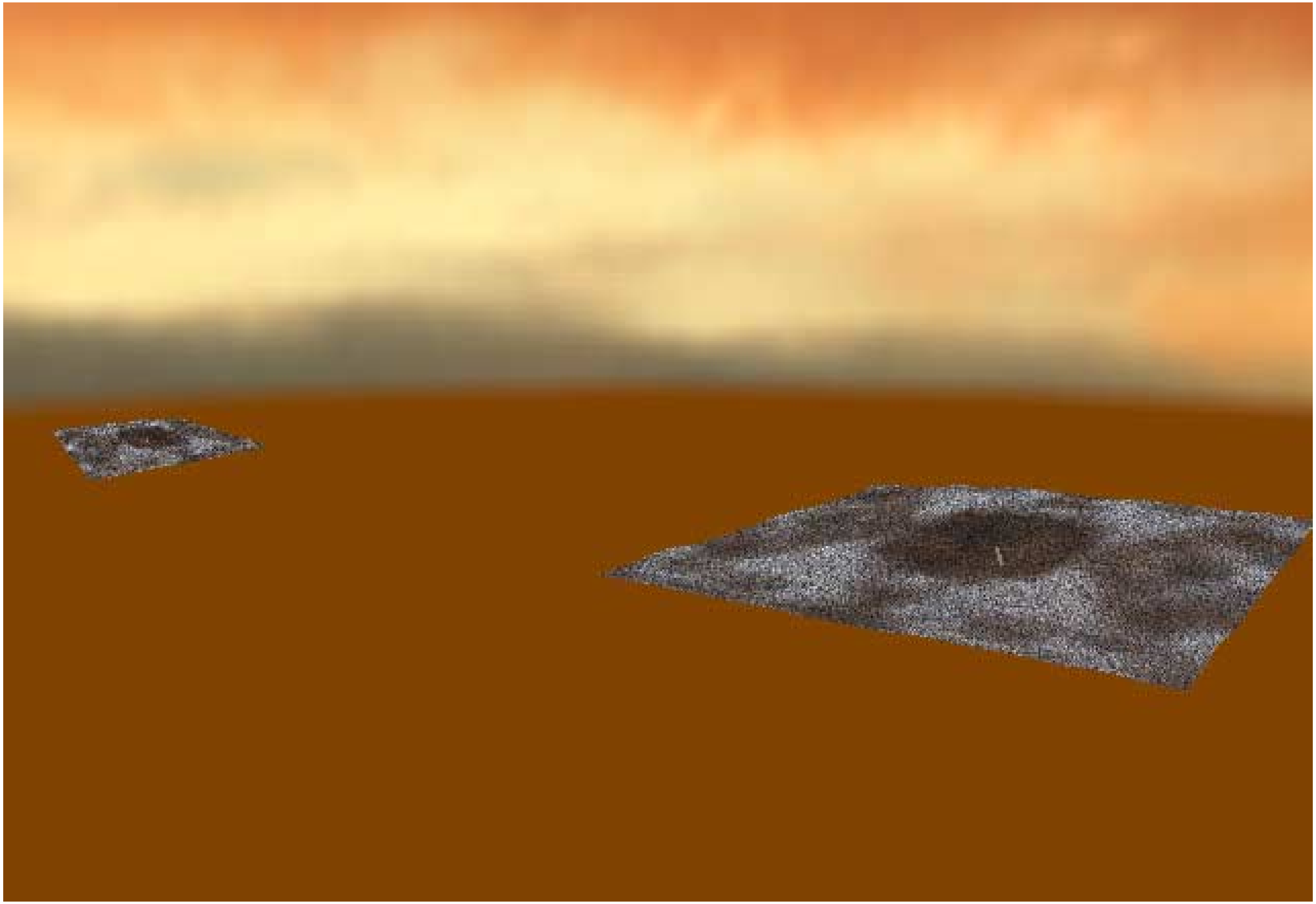
Terrain Boundary in Nautical Miles



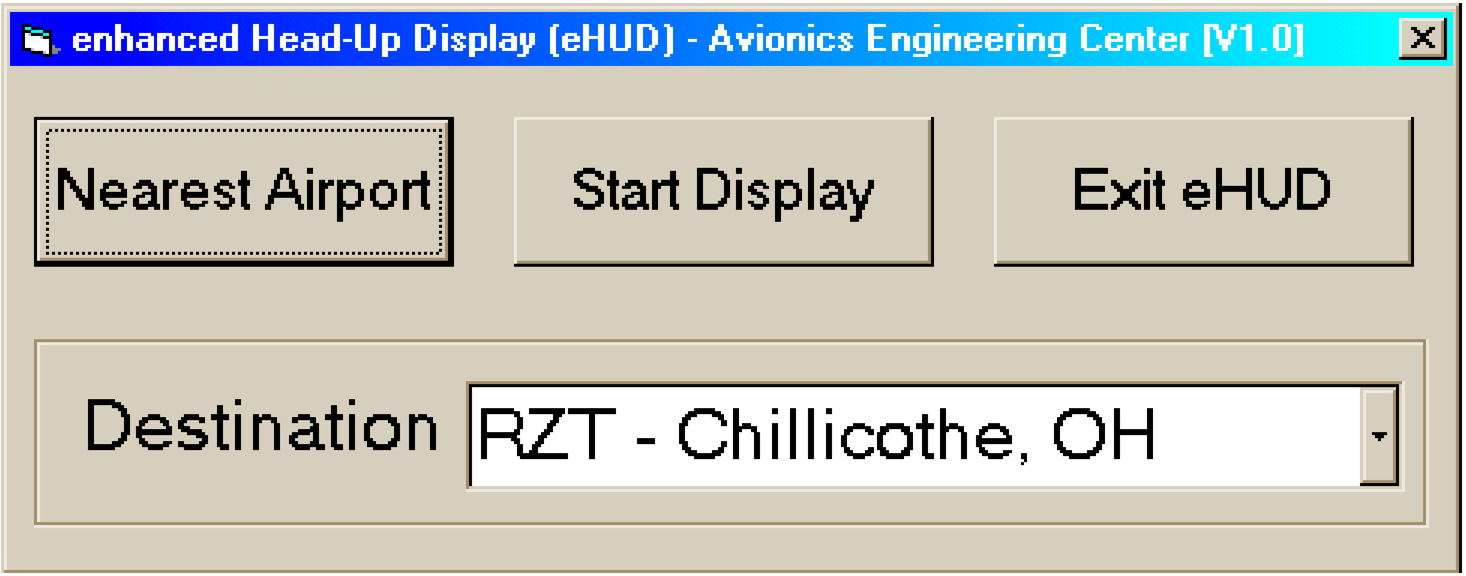
Island Effect



“Island Hopping”



eHUD Initialization



Graphical User Interface (GUI) used to initialize the enhanced Head-Up Display during any phase of the flight.

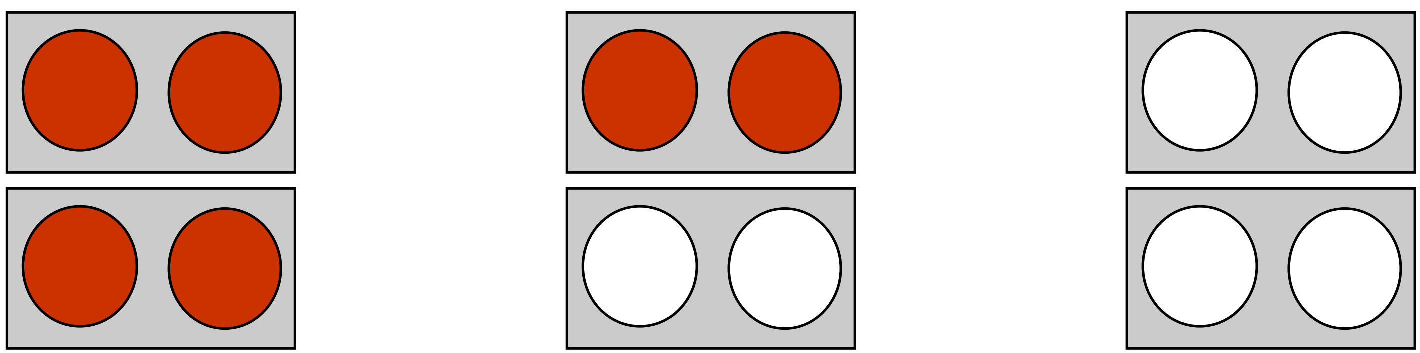
Approach Path Indicators

The depth and height perception on Synthetic Vision Systems (SVS) can be misleading, particularly during the landing phase of the flight. Visual Glide Path Indicators could be implemented to give the pilot an indication of the correct glide slope.

- **Visual Approach Slope Indicator**
- **Tri-Color Visual Approach Slope Indicator**
- **Precision Approach Path Indicator**
- **Pulsating Light Approach Slope Indicator**

VASI

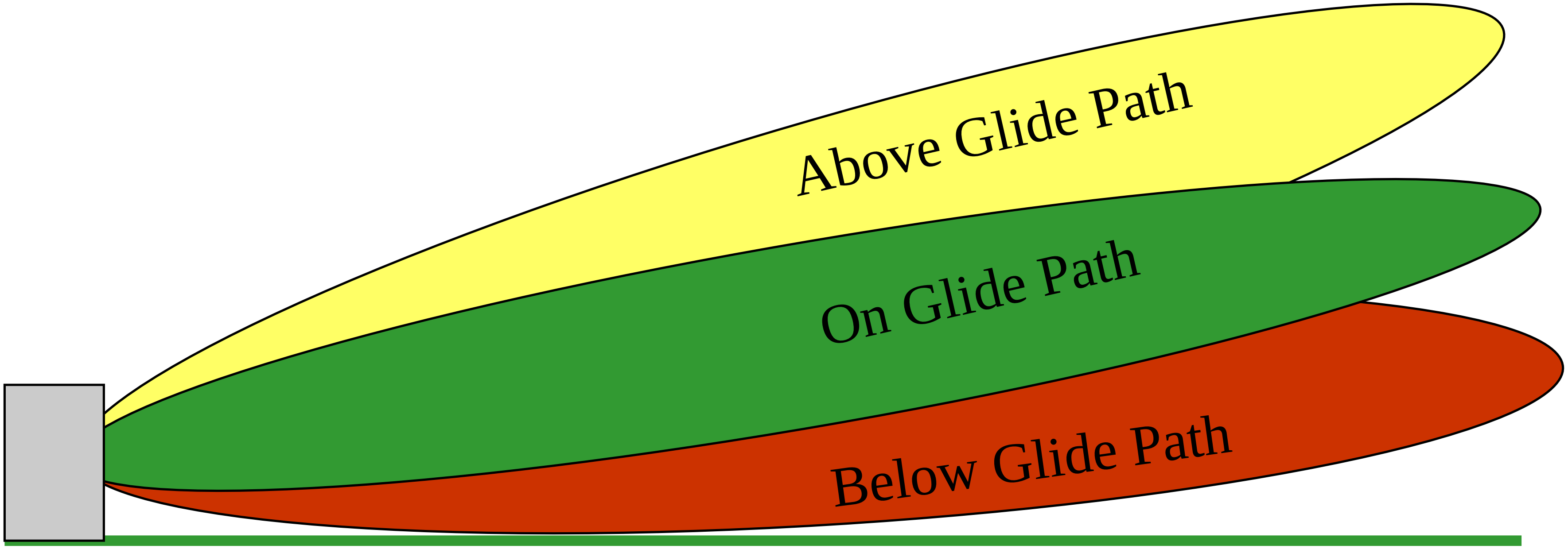
- **Visual Approach Slope Indicator**
  - ➢ **Obstruction Clearance Within 10 Degrees of Extended Runway Centerline out to 4 Nmi**
  - ➢ **2-Bar System**



Below Glide Path   On Glide Path   Above Glide Path

Tri-Color VASI

- **Tri-Color Visual Approach Slope Indicator**
  - ➢**Obstruction Clearance Within 10 Degrees of Extended Runway Centerline out to 4 Nmi**
  - ➢**Single Light Projecting 3 Colors**

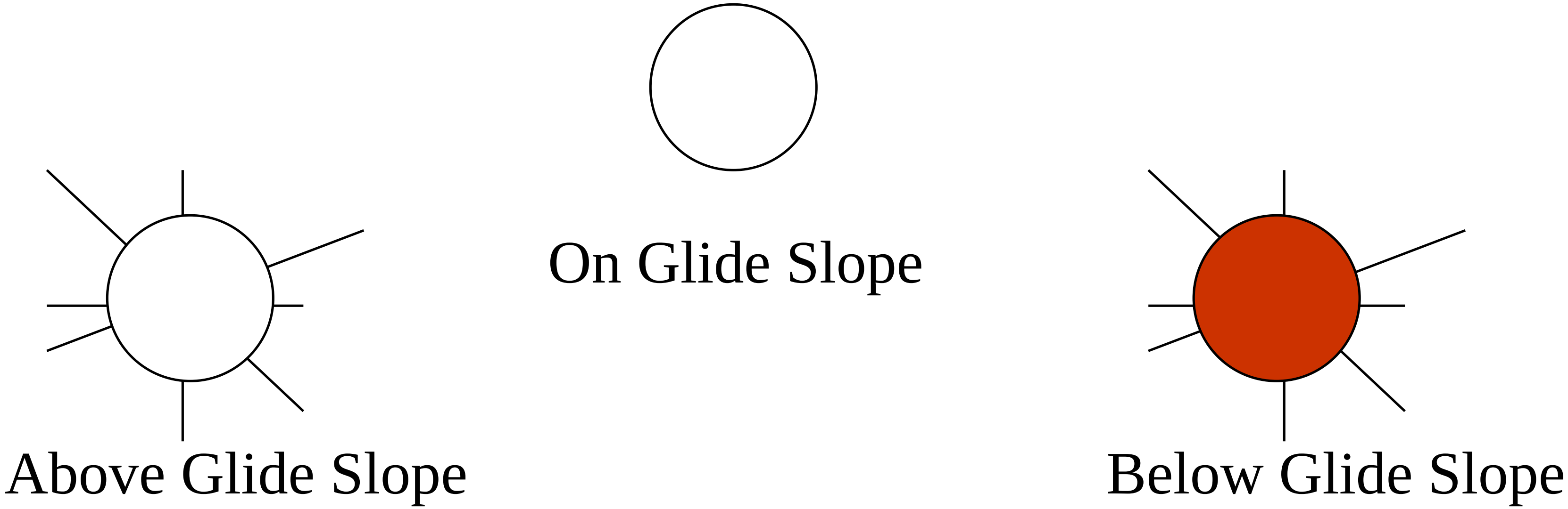


PAPI

- **Precision Approach Path Indicator**
  - ➢**Obstruction Clearance Within 10 Degrees of Extended Centerline out to 4 Nmi**
  - ➢**Four Lights Installed in a Horizontal Row**

PLASI

- **Pulsating Light Approach Slope Indicator**
  - **Obstruction Clearance Within 10 Degrees of Extended Centerline out to 4 Nmi**
  - **Single Pulsating Light**



Concerns and Problems

- Vertical Error Inherent With GPS
- Augmenting System With Accurate Height Information
- Display Perspective
- Ensuring Accurate Information is Relayed Through use of Visual Glide Slope Indicators
- The Many Human Factors Associated With Head-Up Displays

Future Work

- Update the Display to a Modern Implementation of a Head-Up Display
- Set up “Island Hopping” Between Ohio University Airport (UNI) and Ross County Airport (RZT)
- Test Flights Using eHUD with Safety Pilot
- Fine Tuning of eHUD Based on Pilot Response
- Truth Testing Velocity Vector Approach Against INS
- Augment eHUD with Reliable Height Information Such as WAAS when Available

Contact Information

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References

- Kornfeld, R.P., Hansman, R.J., J.J. Deyst, *The Impact of GPS Velocity Based Flight Control on Flight Instrumentation Architecture.* MIT International Center for Air Transportation, Cambridge, MA. Report No. ICAT-99-5, June 1999.
- Eric Theunissen. Integrated Design of Man-Machine Interface for 4-D Navigation (1997) Delft University Press, Mekelweg 4 2628 CD Delft, The Eric's Web page: www.tunnel-in-the-sky.tudelft.nl.
- Dubinsky, J.G., Braasch, M.S., M. Ujit de Haag, "Advanced Flight Display for General Aviation: A Cost-Effective Means to Enhance Safety", Proceedings of the Fifty-Seventh Annual Meeting of the Institute of Navigation, Albuquerque, NM, June 2001.